SCIENCE

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THE RELATION OF FORESTS IN THE ATLANTIC PLAIN TO THE HUMIDITY OF THE CENTRAL STATES AND PRAIRIE REGION

INTRODUCTION

MANY of the dreams or presentiments of the early scientists are now coming true every day. The dreams of the alchemists are now almost within the realization of modern chemistry. The gropings of the early biologists are almost within reach of present-day experimental embryology, and so on practically in every science; at first a presentiment, "a hunch," which can not be substantiated by any scientific facts. This, later, with the accumulation of more accurate observations is often entirely denied or minimized, only to reappear again, not as a presentiment any more, but as a scientifically established fact.

From the earliest times there existed among laymen, and even scientists, a belief that forests exercised an influence upon the climate of entire countries. With the introduction of accurate methods of meteorological observations, this popular conception has seemingly been greatly discredited. All that most of the meteorologists were willing to admit was that forests have a local influence upon climate, extending only over the territory actually occupied by them. Within recent years, just when this view seemed to be completely disposed of, many new facts came up independently in different countries, which point strongly to the possibility of the forest exerting a potent influence upon the humidity of regions lying far away from it. I shall attempt to consider in the light of these new facts the conditions prevailing in the eastern part of the United States, and to establish a relation between the forests of the coastal plain and the southern Appalachians, on the one hand, and the humidity of the central states and prairie region, on the other.

There are three fundamental facts upon which, in my judgment, this relation is based.

1. In the eastern half of the United States there is a marked periodicity in the wind direction. In winter the prevailing winds are from the north and northwest; in summer the prevailing winds are from the south. When the prevailing winds come from the south the entire eastern half of the United States is wet. When the prevailing winds are from the northwest and west the precipitation decreases. Therefore, the precipitation of the eastern half of the United States depends largely upon the prevailing southerly winds which come from the Gulf and penetrate far into the interior of the continent.

2. The evaporation from the ocean plays a comparatively unimportant part in the precipitation over the land; *seven ninths* of the precipitation over land is supplied by evaporation over the land itself and only two ninths is furnished by the evaporation from the ocean. Therefore, the greater the evaporation from the land which is in the path of the prevailing southerly winds, the more moisture must be carried by them into the interior of the continent.

3. The forest evaporates more water than any vegetative cover and much more than free water surfaces. Therefore, forests enrich with moisture the winds that pass over them and contribute to the humidity of the regions into which the prevailing air currents pass.

PERIODICITY OF WIND DIRECTION IN THE EASTERN HALF OF THE UNITED STATES

After Asia, North America is the largest continent in the world. One of the most striking physiographical features of North America is that the mountains run along the meridians and not along parallels. The entire northern part of the American continent has no high mountains except in the western part. As the result of this the central part of the continent does not offer any obstruction to winds from the 30th to 70th degree of northern latitude, that is, from the Gulf of Mexico to the Arctic Sea. Even the Asiatic continent does not have such a large continuous area free of mountains extending along the meridian. There the greatest extension is from the 38th to the 73d degree of northern latitude, that is, from the southern border of the plain of Touran to the northern shores of western Siberia. To the south of the 30th degree extend the waters of the Gulf of Mexico. The mountains on the southern shore of the gulf begin only at 19 degrees of north latitude. The North American continent, therefore, together with the interior lakes forms an expanse for the movement of the air between the tropical and Arctic regions, such as is found outside of it only on large oceans, in the northern hemisphere, on the Atlantic Ocean.

Another climatic peculiarity of the eastern United States which has a bearing upon the question under discussion is the rapid decrease in temperature from south to north. Take, for instance, Labrador; it is entirely an Arctic region where agriculture is impossible. Yet it lies in latitudes at which in Europe and Asia agriculture is still flourishing and large populous cities are found (in 53d to 60th degree northern latitude are found Christiania, St. Petersburg). Florida, on the other hand, between 25th and 30th degree of north latitude, is almost a tropical country. Between Florida and Labrador the drop of temperature for each degree of latitude (60 miles) is for January 2.9° F., for July 1.08° F. and for the entire year 1.7° F.

Comparing the same latitudes in Europe the drop for each degree of latitude is less than half of that for the North American continent. Between the Canary Islands and northern Scotland the decrease in the mean annual temperature for one degree of latitude is only 0.8 of a degree.

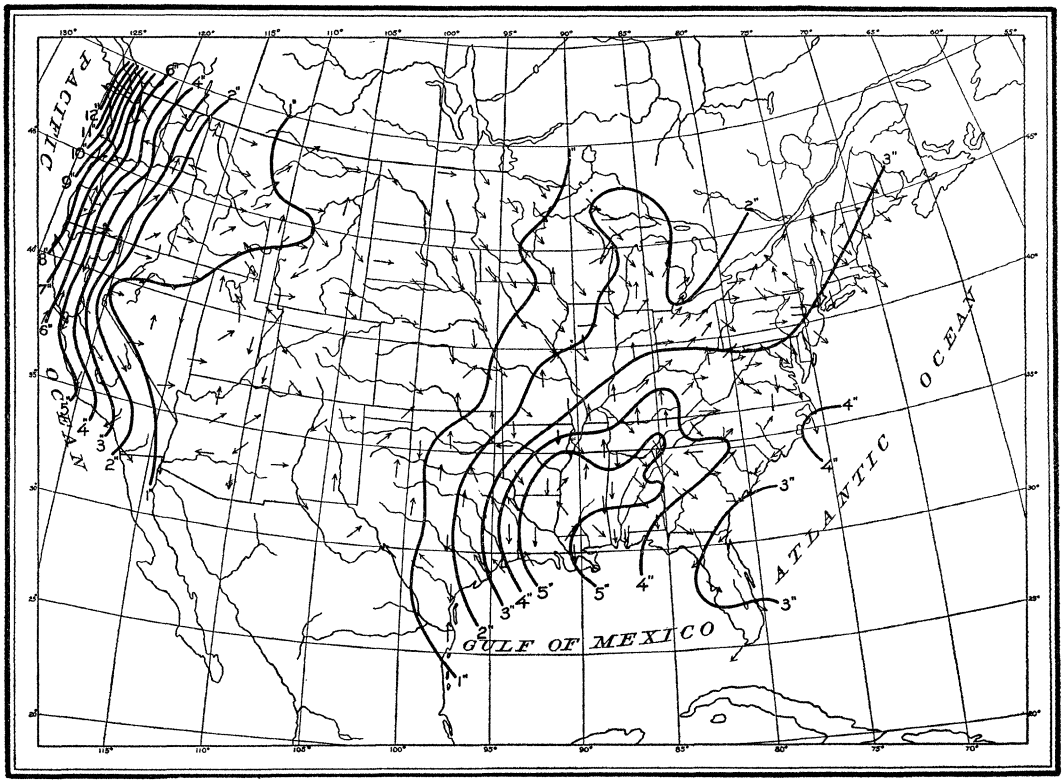
Climatically the North American continent can be divided into three parts:

1. The narrow strip along the Pacific Ocean, which is separated from the interior of the continent by mountain ranges. This narrow strip from the Peninsula of California to the southern shore of the Peninsula of Alaska, from the 32d to the 60th degree of northern latitude, is under the influence of the Pacific Ocean, as it is open to the west, while in the east high mountains separate it from the interior of the continent; and as western winds are, as a rule, the strongest winds in the northern hemisphere, it is only natural that westerly and northwesterly winds prevail in this part of the country both in summer and winter.

2. The region of mountains and plateaus to the east of the Cascades and Sierra Nevada ranges. This extends not only to the Rocky Mountains, but beyond the Rocky Mountains to the 100th meridian. The high plateaus and the low valleys of this region are characterized by extreme dryness and only in the mountains does the snow and rain fall in any abundance. The dryness is due to the fact that the prevailing westerly winds give off the moisture on the western slopes of the Sierra Nevada and Cascades, and become dry winds on the leeward side of these mountains. During the winter the prevailing winds are from the west and northwest, but in the summer the direction of the wind changes considerably, becoming southwesterly. This change in the direction of the wind in summer has been observed even on Pikes Peak, but is still more pronounced in the valleys and on the plateaus.

3. Since the Appalachian Mountains do not offer a climatic boundary, the entire eastern part of the North American continent east of the 100th meridian can be considered climatically as one unit. This climatic region is the largest of the three, including the Atlantic plain, the Mississippi Valley, except the upper part of its western tributaries, and the Lake Region to the Hudson Bay. During winter and partly in the fall and in the early spring the winds in this region come from the west and northwest. These prevailing winds bring cold and comparatively dry air from the interior of the continent. In the spring and early summer these winds are hot and dry. In summer the prevailing winds are from the southeast in Texas, and farther north and east they come from the south and southwest. Professor Henry, in his "Climatology of the United States," says that in midwinter northwesterly winds prevail uniformly over the Missouri Valley and the upper and middle portions of the Mississippi Valley. As the spring advances the region of southeast to south winds spreads northward and eastward from the Texas coast, so that by April it embraces the states of Texas, Oklahoma, Arkansas, Mississippi, Louisiana, Alabama, western Tennessee, Missouri, Kansas, southeastern Nebraska and Iowa. By June the northwest winds of midwinter have been supplanted by southerly winds over practically the whole of the country east of the Rocky Mountains. In autumn the northwest winds become more frequent and as autumn shades into winter they gain the ascendency in the Missouri and Mississippi valleys and the plains states.

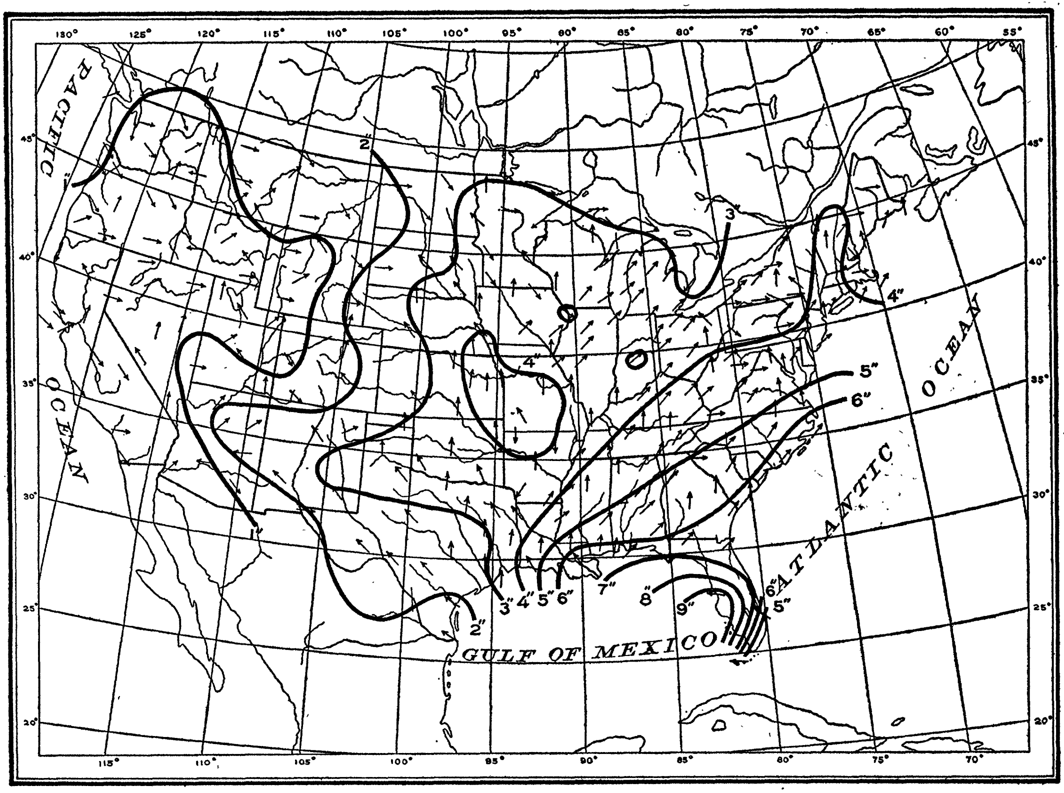
The periodicity is well illustrated on the two maps, on which is indicated by arrows



PREVAILING DIRECTIONS OF THE SURFACE WINDS AND THE MEAN PRECIPITATION IN THE UNITED STATES DURING JANUARY

the direction of the prevailing winds, based on twenty years of continuous records, and by lines the mean precipitation for the months of July and January. The map for the month of July is typical for the summer period and the one for the month of January is typical for the winter period. These maps show, very clearly, it seems to me, that the eastern half of the United States is under the influence of two prevailing winds; one, which originates in the Gulf of Mexico and in the Atlantic Ocean, is mild and humid; the other, which comes from the interior of the continent and from the Rocky Mountain region, is dry and continental in character, that is, dry and cold in winter and dry and hot in the spring and summer.

Another important fact which the records of precipitation and wind direction establish is that there is a most intimate relation between the prevailing southerly winds and precipitation in the eastern half of the United States. It is during the summer period when the entire eastern half of the United States is under the influence of the southerly winds, that most of the precipitation falls over it. On the plains east of the Rocky Mountains the summer rainfall forms from three fourths to four fifths of that of the entire year. In July when the southerly, southwesterly and southeasterly winds extend far into the interior of the continent as far north as North Dakota, and as far west as the foothills of the Rocky Mountains and



PREVAILING DIRECTIONS OF THE SURFACE WINDS AND THE MEAN PRECIPITATION IN THE UNITED STATES DURING JULY

even into eastern New Mexico, and as far east as New England, the precipitation over the entire eastern half of the United States is very heavy. In winter the picture of both wind direction and precipitation is radically changed. The northerly and northwesterly winds have not the same pronounced persistence as the summer winds. Yet through the entire south—Texas, Louisiana and Mississippi—as well as the Atlantic states, the lake states and the central states, the prevailing winds are northerly and northwesterly winds. At the same time there is a perceptible decrease in precipitation through the entire eastern half of the United States, and where in July there fell as much as three inches of rain, in January there is less than one inch, and where in July there fell as much as five inches there is in January less than two inches.

This increase and decrease in precipitation over the eastern half of the United States, with change in the direction of the wind, points to the fact that the eastern half of the United States depends for its moisture upon the prevailing southerly winds, which originate in the Gulf of Mexico and the Atlantic Ocean.

Professor Willis Moore, therefore, is entirely right, it seems to me, when he claims that the Pacific Ocean has little influence upon the precipitation of the eastern half of the United States, as Mr. Gannett and Mr. Bailey Willis have tried to prove. It is possible that some of the vapor that originates in the Pacific Ocean drifts over the tops of the mountains and during winter is drained of its moisture by the excessive cold. This moisure may be precipitated in the form of snow over such states as North Dakota, but the amount can not be very great.

The central interior region of the United States is thus the battleground of two titanic forces, of which one is harmful and the other is beneficial. The beneficial force takes its origin in the Gulf of Mexico and the adjoining ocean, the harmful in the interior of the continent and the Rocky Mountain region, and whether it comes as the warm chinook winds which blow out of the northern Rocky Mountains, or as the dry westerly winds of the upper Mississippi Valley and the western Lake region, occurring especially in the spring and early summer, it always carries in its wake serious injury to orchards and fields.

The central states and the prairie region are geographically at the point where the battle between the two forces is fiercest and the victory is now on the one side and now on the other, being dependent upon the cold and humid, and the warm and dry, climatic cycles as well as upon the seasons of the year.

When the humid southerly winds extend their influence far into the interior of the continent, and overpower the dry continental winds, the central states and prairie region, the granary of the United States, produce large crops. When the dry winds overpower the humid southerly winds there are droughts and crop failures.

The southerly winds on their way from the Gulf of Mexico do not meet any mechanical obstructions. Since the Appalachian Mountains, running in a northeasterly and southwesterly direction, do not hamper their passage, they are capable of penetrating far into the interior of the country and, therefore, determine the amount of precipitation, even in such states as Minnesota, Nebraska, North and South Dakota. The moisture-laden winds from the gulf, as soon as they reach the land and encounter irregularities, are cooled and begin to lose part of their moisture in the form of precipitation.

As long as the air currents are saturated with moisture the slightest cooling or irregularity of the land that causes them to rise will cause precipitation. But as they move inland and become drier the remaining moisture is given off with difficulty and precipitation decreases. The sooner the humid air currents in their passage over land are drained of their moisture the shorter is the distance from the ocean over which abundant precipitation falls; the longer the moisture is retained in the air currents the farther into the interior will it be carried and the larger will be the area over which precipitation will be distributed.

If precipitation over land depended only on the amount of water directly brought by the prevailing humid winds from the ocean, the land would be pretty arid and rainfall would be confined to only a narrow belt close to the ocean. Fortunately, not all the water that is precipitated is lost from the air currents; a part runs off into the rivers or percolates into the ground, but a large part of it is again evaporated into the atmosphere. The moisture-laden currents, therefore, upon entering land at first lose the moisture which they obtained directly from the ocean, but in their farther movement into the interior they absorb the evaporation from the land. Hence the farther from the ocean the greater is the part of the air moisture contributed by evaporation from the land. At a certain distance from the ocean practically all of the moisture of the air must consist of the moisture obtained by evaporation from the land. At least it must form a larger part than the water which was obtained directly by evaporation from the oceans.

The vapor brought by the prevailing winds from the ocean is many times turned over or reinvested before it is returned again to the ocean through the rivers.

If we could reduce the surface run-off, and at its expense increase the evaporation from the land, we should thereby increase the moisture of the passing air currents, and in this way contribute to the precipitation of that region into which the prevailing winds blow. This conclusion is almost axiomatic, and there can be no dispute about it.

"CONTINENTAL" AND "OCEAN" VAPOR

For a long time it has been accepted without any question that all the vapor that is condensed in the form of rain or snow over the land surface is furnished by the evaporation of water from the oceans.

The part which vapor from the ocean plays in the precipitation over land has been altogether exaggerated, and it is hardly possible, therefore, to agree with Professor Moore when he says that "the precipitation over the eastern part of the United States is derived entirely from the evaporation from the Gulf of Mexico and the Atlantic Ocean."

A noted European meteorologist, Professor Bruckner, author of a classical work on the climatic fluctuations, has computed the amount of water evaporated from the ocean surface, land surface and the amount of water which is returned to the oceans and the land in the form of precipitation. The balance sheet of the circulation of water on the earth's surface is made up as follows:

CIRCULATION OF WATER ON THE EARTH'S SURFACE
BALANCE SHEET

	Cu. Miles Vapor	Depth Inches	Per Cent.
A. Entire earth surface (196,911,000 miles).			
Evaporation from water surfaces	92,121	29.5	80
Evaporation from land surfaces	+ 23,270	7.5	20
Precipitation on entire earth surface	115,391	37.0	100
B. Oceans (141,312,600 sq. miles).			
Evaporation from oceans	92,121	41.3	100
Amount of ocean vapor carried to the land (net[2])	+ 5,997	2.8	7
	86,124	38.5	93
C. Peripheral land area (44,015,400 sq. miles).			
Ocean vapor (net)	5,997	8.7	29
Continental vapor from the peripheral land surface	— 20,871	29.9	100
Precipitation over the peripheral land area	26,868	38.6	129
D. Closed interior basins with no drainage to the ocean (11,583,000 miles).			
Evaporation from closed basins	2,399	13.0	100
Precipitation over closed basins	2,399	13.0	100

The continental vapor which is fed from the periphery of the land surface is thus about 21,000 cubic miles. It plays, therefore, an important part in supplying the moisture to the air, even a more important part than the vapor directly fed from the ocean. The peripheral regions of the continents, *i. e.*, the regions tributary to oceans, are capable of supplying *seven ninths* of their precipitation by evaporation from their own areas. The moisture which is carried by the winds into the interior of vast continents, thousands of miles from the ocean, is almost exclusively due to continental vapors and not to evaporation from the ocean.

[2] *I. e.*, the difference between the amount of vapor that escapes from land to the ocean and from the ocean to land.

In the interior enclosed basins the precipitation and evaporation, as a rule, are equal to each other.

Bruckner's figures for entire earth's surface are corroborated also by studies of specific drainage areas. The most interesting study in this connection is that by Professors Francis E. Nipher[3] and George A. Lindsay on the rainfall of the state of Missouri and the discharge of the Mississippi River at St. Louis and Carrollton, Louisiana. Nipher found that the average discharge of the Mississippi River at St. Louis during the ten years ending December 31, 1887, was 190,800 cubic feet per second. The amount of water falling per second upon the whole state during the same interval was 195,800 cubic feet per second, or equal within two per cent. to the discharge of the Mississippi River at St. Louis. If, however, a comparison is made between the total rainfall on the basin draining past St. Louis and the river discharge at this point, it appears that the drainage area of the Mississippi and Missouri Rivers above St. Louis is 733,120 square miles, or over 10 times the area of Missouri. These figures show what small portion of the total rainfall over the drainage basin of the Mississippi River is led into the rivers and conducted back to the sea. It is evident that by far the larger portion of the precipitation that falls over the drainage basin is evaporated back from the land into the atmosphere, and is not returned to the sea through the medium of drainage. These figures show further that the source of precipitation of the Mississippi drainage is from evaporation over the land and not derived from evaporation over the sea. Mr. Lindsay[4] computed the discharge of the Mississippi River at Carrollton, Louisiana, and found that the average for fourteen years was 117 cubic miles per year, or 545,800 cubic feet per second, which is less than three times the precipitation over the state of Missouri.

The central portion of the United States is distinctly a continental region, particularly the prairie region, which suffers from lack of precipitation. On the other hand, large areas in the south and southeast suffer from too much humidity because of large swamps, which is caused not only by excessive precipitation, but also by deficient evaporation. Not only the south and southeastern areas suffer from too much water, but also many portions in the north and northeast, where the evaporation is also very slight. We have, therefore, two extremes on the periphery of the United States: (1) In the states adjoining the Atlantic Ocean and the Gulf of Mexico there is an excess of moisture on the ground, both on account of excessive precipitation and slight evaporation; (2) in the vast interior of the central United States, on the other hand, there is a deficiency of moisture, both on account of the scant precipitation and of the intense evaporation. Is there not some connection between these two extremes? Is it not possible that changes which take place in one part of this vast region may exert some influence on the condition of the other? We have seen that in the central states in summer the prevailing westerly and northwesterly winds give way to southerly and southeasterly winds. In other words, in the summer the central states are under the influence of moist

[3] Francis E. Nipher, "Report on Missouri Rainfall, with Averages for Ten Years ending December, 1887," *Transactions of the Academy of Science of St. Louis,* Vol. V., p. 383.

[4] Geo. A. Lindsay, "The Annual Rainfall and Temperature of the United States," *Transactions of the Academy of Science of St. Louis,* June, 1912.

winds, just at the time when the evaporation is the greatest and the forest vegetation is especially active. It seems, therefore, that the amount of moisture evaporated within the more moist region of the United States can influence the conditions of humidity, not only in the States close to the ocean, but also in the region into which the prevailing moist winds flow. The more moisture there is evaporated from the ground in the southern and southeastern portions of the United States, the moister must be the air in the central states and the more precipitation must fall there.

FOREST THE GREATEST EVAPORATOR OF WATER

What are the sources from which the evaporation on land is the greatest? The evaporation from a moist, bare soil is, on the whole, greater than from a water surface, especially during the warm season of the year when the surface of the soil is heated. A soil with a living vegetative cover loses moisture, both through direct evaporation and absorption by its vegetation, much faster than bare, moist soil and still more than free water surface.

The more developed the vegetative cover the faster is moisture extracted from the soil and given off into the air. The forest in this respect is the greatest desiccator of water in the ground.

The latest experiments of Russian agronomists and foresters, corroborated by similar observations in France and Germany, have proved that in level or slightly hilly regions the forest has a desiccating effect upon the ground, causing the water table to be lower under forest than in the adjoining open fields. Professor Henry, in his recent investigations on the effect of forests upon ground waters in level country, has found that the minimum depression of the water table produced by the transpiration of forest trees in the Mondon forest near Luneville, France, amounts to 11.8 inches. With a porosity of the soil strata ranging between 45 and 55 per cent., such depression would correspond to a rainfall of 5.9 inches, which amount to 21,443 cubic feet per acre. This amount of water given off by the forest into the air obviously contributes greatly to the moisture content of the atmosphere above the forest. Dr. Franz R. von Höhnel, of the Austrian forest experiment station at Mariabrunn, carried on observations for a period of three years (1878–1880) upon the amount of water transpired by forests. He found that one acre of oak forest, 115 years old, absorbed in one day from 2,227 to 2,672 gallons of water per acre, which corresponds to a rainfall of from 0.09 to 0.115 inch per day, or 2.9 to 3.9 inches per month. Taking the period of vegetation as five months, the absorption of water would be 158,895 cubic feet, which represents a rainfall for this period of 17.7 inches. This amount of water is given off merely through transpiration from the leaves and does not include the physical evaporation from the surface of twigs, branches, and leaves. These figures, while only approximate, give an idea of the enormous quantities of water given off by forests into the air, which has justly given them the name of the "oceans of the continent."

The most valuable and complete work on the subject is by Otozky, a Russian geologist and soil physicist, which appeared as a publication of the forest experiment stations. Otozky worked up an enormous amount of observations, both his personal and those furnished him by other people, and did not find a single contradictory fact. His conclusion is that the forest, on account of its excessive transpiration, consumes more moisture, all other conditions being equal, than a similar area bare of vegetation or covered with some herbaceous vegetation. The amount of water consumed by forests is nearly equal to the total annual precipitation; in cold and humid regions it is somewhat below this amount and in warmer and dry regions it is above it.

This enormous amount of moisture given off into the air by the forest, which may be compared to clouds of exhaust steam thrown into the atmosphere, must play an important part in the economy of nature.

If the present area occupied by forests in the Atlantic plain and the Appalachian region were instead occupied by a large body of water, no meteorologist would hesitate for a moment to admit that the water surface has a perceptible influence upon the humidity of the central states and prairie region. Should not, therefore, forests which give off into the atmosphere much larger quantities of moisture than free water surface, have at least a similar influence upon the regions into which the prevailing air currents flow.

If the southern and southeastern winds, in their passage toward the north, northwest and northeast, in the spring and summer, did not encounter the vast forest areas bordering the shores of the Gulf of Mexico and the Atlantic coast and those of the southern Appalachian, and, therefore, were not enriched with enormous quantities of moisture given off by them, the precipitation in the central states and the prairie region would undoubtedly be much smaller than it is now.

What would be the effect of complete or even partial destruction of forests in the Atlantic plain and in the southern Appalachian Mountains upon the humidity of the continental portion of the United States? As the mean temperature in the eastern part of the United States drops rapidly from south to north, the moisture-laden air currents upon entering land would be cooled off and rapidly drained of their moisture within a comparatively short distance from the ocean. The sandy soil which is so characteristic of the southern pine belt of the gulf and south Atlantic States would rapidly absorb the rain which would percolate into the ground, without returning much of it into the atmosphere. The rain falling upon the slopes of the mountains would rapidly run off into streams. While direct evaporation from the ground not sheltered by forest cover may become greater, yet the more rapid run-off and the absence of transpiration by trees would necessarily reduce the total amount of water evaporated into the atmosphere. The land, were it even taken up for agriculture, would not return such large quantities of rain into the atmosphere as the forests did. The inevitable result would be that less moisture would be carried by the prevailing winds into the interior of the country, and therefore less precipitation would occur there. Such is the influence of forests in a level or a hilly country.

Whether forests in the mountains have the same effect as forests in level countries upon the precipitation of the regions into which the prevailing winds that pass over them blow, is difficult to determine. The problem is more complicated for the reason that high mountain chains exert an influence upon the direction of the winds, not only by presenting a mechanical obstruction to the free passage of the air, but also on account of the difference in the heating of the different slopes. A moist current of air in passing over a mountain chain undergoes several changes. It is known that the air in ascending becomes cooler. The temperature of not fully saturated air decreases 1° F. for every 182 feet of ascension. In ascending the mountain slope the water-holding capacity of the air decreases until the saturation point is reached, and fogs, clouds and precipitation begin to form. The further cooling of the air is counteracted to some extent by the heat that is given off in the process of the condensation of vapor. This further cooling, therefore, proceeds only at the rate of about 0.5° F. for every 182 feet of ascension, or only half as much as when the air is dry. After the air current has passed the crest of the mountain and lost an amount of moisture corresponding to the temperature which it had at the time of passage, it descends on the leeward side and becomes heated.

In its descent it absorbs the fogs and clouds. In this process it consumes some heat. The further heating goes on at the rate of 1° F. for every 182 feet of descent. The more moisture there is extracted on the windward side of the slope, the greater is the temperature of the air on the leeward side.

If, for instance, an air current before ascending had a temperature of 50° F. at a barometric pressure of 30 inches, and the crest over which it passed was 9,900 feet high, then, on the leeward side at the same altitude at which it began to ascend, it would not have a temperature of 50° F., but of 77° F. at a relative humidity of 21 per cent. At other ascensions by the same current of air, the same changes would take place. But new precipitation, as a rule, begins on the next chain of mountains only at an altitude equal to that of the crest of the previous mountain chain over which the current of air has passed.

Professor Mayr[5] has shown that wherever there are several parallel chains of mountains perpendicular to the moist-air current, such as are found on the Pacific coast, of which each one is higher than the previous one, the forest appears in each consecutive mountain chain only from an altitude equal to the altitude of the top of the preceding chain over which the air current has passed. Between the mountain chains there remain treeless, dry valleys. This is strikingly observed in the Pacific coast and Rocky Mountains, as well as in Caucasus and Turkestan.

As a rule, the moist air currents, in passing over wooded slopes, being chilled, deposit most of their precipitation on the windward side. It is only in exceptional cases, such as when the air that passes over the wooded slopes is not fully saturated, or when warm currents rise from below, that the air current, instead of depositing moisture, becomes enriched with moisture and carries it over the crest to the regions lying farther on its way.

This may occur on southern slopes, which are apt to become warm. The influence of wooded windward slopes upon the humidity of the regions lying to the leeward side of the mountain chains, therefore, varies. It is apparent, however, that, while the forests in the mountains at right angles to prevailing moist winds have a marked influence upon local precipitation, their influence upon the humidity of regions lying to the leeward of them can not, on the whole, be very great.

CONCLUSIONS

If the effect of mountainous forests upon the precipitation of regions lying in the lee of them is not entirely clear to us, the effect of forests in wide plains of continents, especially in the path of moist winds, can not be doubted. By increasing the evaporation from the land at the expense of surface run-off they enrich with moisture the passing air currents, and in this way help to carry it in larger quantities

[5] "Waldungen von Nord Amerika."

into the interior of continents. The destruction of such forests, especially if it leaves the ground bare or partly covered with only weak vegetation which does not transpire large quantities of water, must inevitably affect the climate, not so much the climate of the region in which the destruction took place but the drier regions into which the prevailing air currents flow.

I realize, of course, that direct proof of this climatic influence quantitatively expressed is still lacking. It will take many decades before direct observations of such a character will be secured. If, however, the premises upon which the discussion rests, namely, that the precipitation of the eastern half of the United States is intimately connected with the prevailing south winds, that evaporation from land contributes more to the precipitation over land than evaporation from the ocean, that forests evaporate more water than free water surface, or any other vegetation, then forests in the path of prevailing winds must necessarily act as distributors of precipitation over wide continents.

What practical deductions can be made from these facts?

1. Forests must be protected not so much in localities which already suffer from lack of moisture as in regions which lie in the path of prevailing winds and are still abundantly supplied both with ground water and precipitation. In the dry regions large bodies of forests may have the opposite effect upon the available water supply. There only forests growing along rivers may contribute to the humidity of the region. There rows of trees or windbreaks surrounding fields and orchards, by preventing the drifting of the snow and decreasing the activity of the wind, will act more as conservers of moisture in the soil than solid bodies of timber. Therefore, the care with which forests should be protected in the eastern half of the United States must increase from north to south and from west to east.

2. In the Atlantic plain and southern Appalachians, which are the gateway for the prevailing winds from the Gulf of Mexico and the Atlantic Ocean, forests must be especially maintained.

(*a*) On moist soils, provided the excess of water or the substances contained in it do not prevent their development, because the moister the soil on which forests grow the more moisture they evaporate. For this reason swamps, since they contribute less to the moisture contents of the air than crops or forests and lose considerable water by surface run-off, must be drained, as by doing this an increase of the evaporation at the expense of surface run-off may be secured.

(*b*) On sandy soils. Forests on sandy soils readily absorb water through the roots and evaporate it into the atmosphere. Denuded of forest cover, sandy soils readily absorb rainwater which percolates into the ground and often reaches the sea by underground channels without being returned to the atmosphere.

(*c*) On steep slopes and rocky places; the removal of forests on such places inevitably leads to an increase in the surface run-off and to a corresponding decrease in local evaporation.

3. If clearing of the forest is a necessity it should be done only under condition that the cleared land is to be devoted to intense cultivation, as, after forests, crops contribute most to the moisture of the air. The highest organic production, therefore, is in harmony with the safeguarding of the humidity in the regions which lie in the path of the prevailing winds. Cleared land that becomes waste or poor pastures or grows up to weak vegetation, means so much evaporation lost to the passing air currents.

The effect of forests upon climate, if viewed as a local influence, must necessarily be insignificant. First we must not forget that whenever we compare a forest with an open field adjoining it, the open field itself is under the influence of the forest and can not give a proper conception of the true effect of the forest.

Such a meteorological authority as Lorenz Liburnau, at the end of his monumental work on "The Results of Forest Meteorological Observations," remarks that his data and conclusions apply only to the influence which the forest exerts while it exists, but do not extend to conditions which may rise upon its complete destruction. "If, for instance, according to our observations in the Carpathian foothills, it appears that the influence of the forest upon the neighboring country is only insignificant, this does not indicate that a complete destruction of all the existing forests will produce here also only insignificant climatic changes. Very likely that, if the forest were completely destroyed, the difference would be much greater than the difference that exists now between the climate of the forest and its neighboring areas."

Local observations, no matter how accurately and minutely carried out, can not lead us to the solution of the problem. The method of attack itself is wrong. It is only by approaching the problem from a much broader standpoint, by rising mentally to a height which opens wide perspectives both to the distant shores of the Gulf of Mexico and the Atlantic Ocean and to the most interior portions of the continent; only by following the moist south winds on their way from the gulf through the gateway of the North American continent, the Atlantic plain to the Prairie region, by considering how many times the moisture carried by the wind is dropped in the form of precipitation and raised again as evaporation, by studying the part which the vegetative cover plays in this circulation of water on the land, especially the dense coniferous forests, that we can grasp the problem in its true light.

RAPHAEL ZON
U. S. FOREST SERVICE

LESTER FRANK WARD

LESTER FRANK WARD, A.B., LL.B., A.M., LL.D., was born at Joliet, Illinois, June 18, 1841, and died in Washington, D. C., April 18, 1913.

Philosopher, sociologist, paleobotanist—few men in these days of specialization have earned such enviable reputation along such widely divergent lines of thought as are designated in these terms, which imply both a deep thinker on abstract subjects and a careful student of concrete facts. The scope of his mentality was remarkable, not alone in the ability to master any subject in which he chanced to become interested, but also in the ability to completely dismiss any subject from his mind whenever he wished to concentrate attention on something entirely different, and to subsequently resume the original trend of thought without apparent effort.

His reputation as a student of and writer on ethical and sociological subjects assures that he will not be forgotten or fail of suitable recognition by those who are best qualified to discuss his activities in such connection. It is my privilege to merely say a few words in regard to Dr. Ward as a paleobotanist.

Our personal acquaintance began in 1882, about a year after his appointment as assistant geologist on the staff of the United States Geological Survey. His special work was in connection with the problems of paleobotany and their relations to geological investigations, the importance of which was just beginning to attract some attention, and it was my good fortune to enlist his interest and to subsequently enjoy the privilege of his cooperation and kindly criticism in my paleobotanical studies and to feel the inspiration of his con-